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An Overview on Geothermal Potential Assessment and Geothermal Development in Vietnam

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ABSTRACT

There were several projects studying and assessing the geothermal potential in Vietnam until now. The results of these study projects show that the geothermal potential in Vietnam is not so big. According to the preliminary assessment, it is possible to exploit 680 MWe from development of highest potential geothermal prospects. Along with the geothermal development in the world, geothermal in Vietnam is also more well known by the government and the people nowadays, not only about hydro-geothermal but also about ground source heat pump as well as Enhanced Geothermal System. Not only the geothermal energy potential in Vietnam is not so big through studies, but it is also not developed significantly. Currently there is no geothermal power plant in Vietnam but the first geothermal project for power generation was licensed and is at the exploration stage now. The geothermal utilizations until now is only for bathing, swimming pool, spa, therapy, tourism, and aquaculture. For a geothermal heat pump, only one experimental project has been installed since 2016 and its energy efficiency is about 45%. According to the survey on the barriers for geothermal development conducted in 2018, the results show that the biggest barriers are the very high initial investment and high risky for the geothermal development.

1. INTRODUCTION

Geothermal is considered as a geological resource managed by the government of Vietnam. The Government conducts initial research studies and assessment on geothermal potential including; hydro-geothermal, shallow geothermal and, of course, enhanced geothermal system.

According to the previous studies and investigation, the development of geothermal resources has been preliminarily evaluated and may have temporarily proposed plans to develop the most promising geothermal resources.

In order to conduct development of a geothermal resource, first of all, it is necessary to apply for an exploration license from the government through the Ministry of Natural Resources and Environment after a resource assessment survey. In order to carry out the construction of a geothermal power plant, it is necessary to get permission from the government through the Ministry of Industry and Trade and must reach an agreement to sell electricity with Electricity of Vietnam (EVN) that is the representative agency for the government to manage electricity in the whole country.

Currently, geothermal has no preferential policies while wind, solar, biomass and small hydro have a priority policy, especially price subsidies (Fit-in-Tariff). However, like other forms of renewable energy that have now grown relatively strong such as solar power, the investors must also invest and have negotiations with the government to be able to reach a regulation to determine the electricity sale price in a specific way to develop this energy source.

2. GEOLOGY BACKGROUND

2.1 Tectonic outline

The territory of Vietnam is apart of the South China Plate and Indochina Plate and can be divided into five the tectonic divisions as structural blocks (Fig. 1). They are the Northeast (NE), Northwest (NW), Truongson, Kontum and Nambo blocks. The NE block is recognized as part of the former China continent. For the stratigraphy and igneous rocks, there range from the Late Proterozoic to Quaternary. The NW and Truongson blocks, with the thickest Paleozoic strata in Vietnam are recognized as NW－SE trending Paleozoic folded systems but there are some differences in tectonic development between them, especially in the Late Paleozoic. The Kontum block is an uplifted massif. The oldest stratigraphy of the Archean is found there, but Paleozoic rocks are mostly absent. The Nambo block is a part of the Malaysia - Miami "geosynclinal system" and recognized as a continental rift filled with thick (6km) Cenozoic deposits (De et al. 1986).

2.2 Stratigraphy

The rocks of Vietnam range from Precambrian to Quaternary. The strata of each (E, NW, Truongson, Kontum and Nambo) is different (Fig. 2).

Precambrian stratigraphy

The Precambrian formations in Vietnam are found along the axis of the Fansipan range in the Red River valley（NW block) and in the Kontum massif (Fig. 2).

***Archean metamorphic rocks**:* In the Kontum massif the Archean granulites, grouped into the Cannak complex which is the oldest stratigraphic unit in Vietnam, are found in close connection with autochthonous plutons of alkali-charnokites (orthopyroxene-bearing granites). The thickness of the complex has been estimated to be > 4000m.

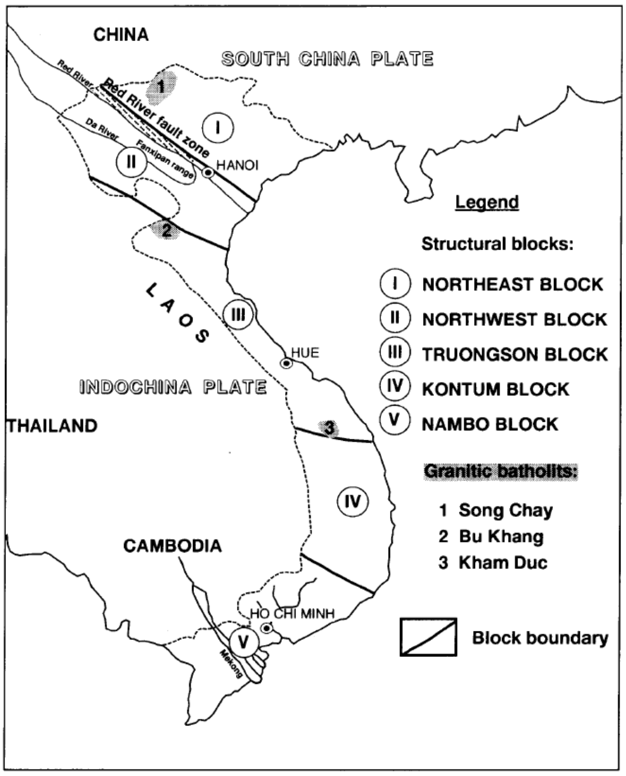

Figure 1: Tectonic divisions of the territory of Vietnam (Tran N.N., 1995)

Lower Proterozoic metamorphic rocks: Lower Proterozoic rocks are found in the Kontum massif and in the cores of the Fansipan range and Red River fault zone (Fig. 2). The general thickness of the complexes has been estimated to be 2500 -3000m. The lowest part of the complexes is mainly composed of amphibolite－biotitegneisses, hornblend - biotite plagiomigmatite and intercalations of amphibolites. The principal constituents of the upper part are sillimanite-biotite-garnet gneisses and schists. There are also graphite bearing schists and intercalations of quartzite, lenses of marbles and calciphyres in this part.

Upper Proterozoic metamorphic rocks: Upper Proterozoic metamorphic rocks, with a strata thickness of 1000-1200m, are widespread and form a large (50－60km wide) belt bordering the Kontum massif. They are composed of amphibolite with garnet and cummingtonite, with intercalations of garnet-cummingtonite amphibolite, marble and plagioclase-diopside schists in the lower part. The upper part is built up of two-mica schist, gneiss, quartzite, amphibolite and marble. In the NW block, the Upper Proterozoic rocks consist mainly of two-mica schists and sericitic schists intercalated with quartzite and marble. The strata thickness has been estimated to be 900－1000m.

Paleozoic stratigraphy

Paleozoic strata in Vietnam are widespread in the NE, NW and Truongson blocks, but are absent in the Kontum and Nambo blocks Fig. 2).

Lower Paleozoic strata: The 1300－2000 m thick Middle Cambrian-Lower Ordovician strata that consist mainly of limestone, mudstone and sandstone have been divided into two types, namely the Changpung and Thansatypes. The latter is distributed in the NE block. Whereas the former is in the NW and Truongson blocks.

Upper Paleozoic stratigraphy: In the NE and NW blocks the lowest Devonian strata, with a thickness of 600-700m, are continental formations containing fresh water fish fossils, unconformably overlying the Lower Paleozoic formations; in the lower course of the Da River (NW block) there are carbonate-terrigenous formations conformably resting on Silurian formations and containing fossil assemblages of brachiopods. The Middle Devonian Strata are mainly composed of 500 m thick Carbonate formations containing abundant remains of corals. The Upper Devonian strata, with a thickness of 200m. The strata contain are bedded siliceous limestone, shale, and siliceous rocks, containing Frasnian and Famennian conodont assemblages (Thanh et al., 1986; Tri et al., 1977).

Mesozoic stratigraphy

In Vietnam the Mesozoic strata consists of Triassic and Jurassic marine sedimentary and Volcano-Sedimentary rocks, and Cretaceous red Continental formations. They are distributed in Mesozoic grabens. In the NE block the grabens trend from NE-SW to sub W-E, where as in the other bocks they mostly trend NW-SE.

The Triassic formations mainly consist of terrigenous deposits, volcanics, and limestone containing abundant assemblages of pelecypods. The Norian-Rhaetian consists of coal－bearing deposits containing the famous Hongai flora (Khuc and Thu, 1986).

Cretaceous red continental formations mainly consist of sandstone, siltstone, light violet to red brown shales and conglomerates. In some places, there are salt-bearing formations (Thu and Tien , 1986).

Tertiary stratigraphy

Tertiary (mainly Neogene, in some areas with Upper Paleogene) deposits are of limited quantity and belong to three types: 1acustrine with the intercalation of volcanic rocks, lagoonal or deltaic, and marine. Lagoonal or deltaic formations are distributed in the Hanoi and Mekong basins. Marine formations are deposited only on the continental shelf of Vietnam. Basalts are also found in the same deposits (Dzanh, 1986).

Quaternary sediments

Quaternary formations in Vietnam consist of two series: deltaic sediments distributed in the Hanoi & Mekong basins and coastal plains and basalts that are widely distributed in the central highland.

2.3 Igneous activity

The magmatic evolution in Vietnam is divided into five episodes: Archean, Early Proterozoic, Early－Middle Paleozoic, Late PaleozoicLEarly Mesozoic and Late Mesozoic－ Cenozoic. Some episodes are subdivided into Cycles (Quyen, 1986).

2.4 Intrusive bodies

Intrusive bodies are found in many places in Vietnam, at different episodes and with varying compositions. The episodes: Archean episode, Early Proterozoic, Early－Middle Paleozoic, Late Paleozoic－Early Mesozoic and Late Mesozoic – Cenozoic. The compositions: ultramafic to granitic, plagiogranite and migmatite, ultramafic to granitic, commonly granodiorite, granite, high－alumina granitoid, alkaline granite and alkaline syenite. The ages of the intrusive bodies have been estimated based in part on radiometric data, but mostly on comparison with relative ages of associated volcanic formations.

2.5 Volcanic formations

The youngest volcano activity was occurred in Vietnam in 1923 but was located at offshore of the central Vietnam. In the mainland, the youngest volcano also ceased operation 11,000 years ago in the Central Highlands. Volcanic formations are found in Vietnam throughout geological time. The thin pre-Mesozoic Volcanic formations are found in a wide variety of geological structures , the thick (＞800m) sequences of Mesozoic (Middle Triassic and Jurassic) volcanic formations are found in many Mesozoic volcanic grabens and the Paleogene and Neogene - Quaternary volcanic formations cover the modern relief of some areas in Vietnam (Quoc N.K., 1986 and Tran N. N., 1995).

3. GEOTHERMAL RESOURCES AND POTENTIAL

From the studies and investigations of hot mineral water sources combined with geological features, structural geology in the territory of Vietnam, the sources of these hot mineral water have been distributed on the geological structure blocks those are equivalent to geographic regions including: North-west region covers the Northwest Block; North-east region covers the Northeast Block; North-plain region is the red-river delta between Northwest and Northeast Blocks; North-central region covers the Truongson Block; South-central region covers the Kontum Block and South-plain region covers the Nambo Block.

The geothermal sources shown on the ground are the hot water sources. According to projects investigating hot mineral water sources, in Vietnam, nearly 300 sources of temperature > 30°C have been found and listed in the list of hot mineral water sources in Vietnam (Vo et al., 1998). Hot water sources have been classified according to the temperature shown in Table 1. The table 1 shows that there are 41 sources of hot water with temperatures ranging from 61°C to 100°C, accounting for 15% of all hot water sources in Vietnam. There are four sources of hot water with a temperature of > 100°C, accounting for 1.5% of all hot water sources in Vietnam. Of these four hot mineral water sources, there is only one source at Truongson Block that is the natural source found on the surface of the ground but the others appears in boreholes with the depths of more than 2,000 m in the Red River Delta.

In general, geo-tectonic features are relatively reflecting the geothermal potential in Vietnam. Vietnam does not have volcanic geothermal resources. The geothermal sources are mainly due to the deep cooling magma or due to the geothermal gradients.

Since 1993 to 2013, there were four projects of study and investigation on the geothermal potential in Vietnam territory including the South Central region, North Central region, Northwest and Northeast of northern delta. In term of geological structures, the investigated areas cover on four blocks excepting the Nambo block. These researches consist of the geochemical and geological reconnaissances for preliminary assessment of the geothermal prospects in the four regions (Hoang et al. 1996 and Cao et al., 2005 and 2013).

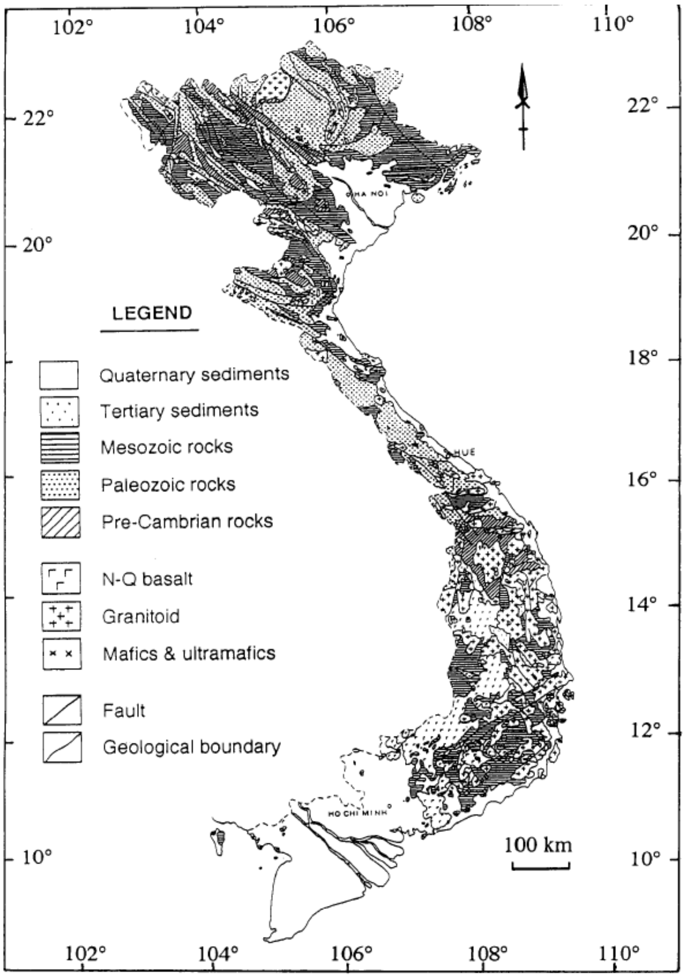

Figure 2: Geological map of Vietnam (Tran & Nguyen, 1986).

Table 1: The hot water sources with the temperatures > 30^{0}C in Vietnam territory (Vo C. N., 2001).

Temperature	Region or Block						Total	Compare with the total (%)
	Northwest	Northeast	Red river delta	Truongson	Kontum	Nambo		
30 - 40^{O}C	35	6	9	11	27	52	140	52.0
41 - 60^{O}C	38	3	3	19	20	1	84	31.2
61 - 100^{O}C	6	2	2	11	20	0	41	15.2
>100^{O}C	0	0	3	1	0	0	4	1.5
Total	79	11	17	42	67	53	269	
Compare with the total (%)	29.4	4.1	6.3	15.6	24.9	19.7		100

These studies have investigated and evaluated a total of 240 hot water sources with temperatures greater than 30^{0}C, equivalent to about 88% of the total hot water sources found in the Vietnamese territory. The researches were aimed at further understanding the origin and characteristics of geothermal resources and also to assess the potential for developing them for the purpose of socio-economic development and especially for construction of geothermal power plants.

Through investigation, it can be seen that most geothermal waters belong to HCO_3-type water. There are some waters in Northwest of northern delta belong to SO_4 type and only some waters are located in the South Central Coast or Northeast of northern delta is of CL- type. The studies show that these CL- type waters are likely to be influenced by seawater.

In the surveys, the research groups attempted to collect gas samples from the geothermal sources but only obtained a total of 40 samples in which the Northwest of northern delta obtained 22 samples, the North Central region obtained 7 samples, the South Central region has 11 samples. No gas samples were collected in the Northeast of northern delta. The chemical components analyzed from gas samples were CO_2, N_2, Ar, He, H_2S.

Base on surveys, research and assessment by methods of thermal fluid chemistry combined with analysis of geological factors, there were 25 potential geothermal resources those can be selected for power generation purpose: Northwest of northern delta has 8 sources; Northeast of northern delta has 6 sources; North Central has 5 sources and South Central has 6 sources. The reservoir's temperatures of these geothermal resources were estimated by geothermometers combined with other chemical characteristics of thermal fluids (Tab. 2).

In addition to the above projects those were implemented by the Vietnamese geologists, the international geothermal experts and scientists had also studied and evaluated many geothermal resources in South Central Vietnam and made the valuable reports (KRTA, 1993 and Gianelli et al, 1997).

Table 2: The temperatures in the reservoirs computed by geothermometers

No.	Name and the location of geothermal resources	Temperature (^0C)	
		Suface	Reservoir
Northwest Block			
1	Na Hai (Dien Bien province)	78.0	192
2	Pom Lot (Dien Bien province)	74.0	150
3	Na Ban (Lai Chau province)	36.7	199
4	Muong Loi 2 (Dien Bien province)	36.5	140
5	Ban Sang (Dien Bien province)	50.5	225
6	Nam Pam (Son La province)	55.5	192
7	Pac Ma (Lai Chau province)	62.5	169
8	Quynh Chau (Thai Binh province)	37.2	187
Northeast Block			
9	Bo Duot (Ha Giang province)	71	198
10	Na Chi (Ha Giang province)	32	183
11	Quang Ngan (Ha Giang province)	62	188
12	Quang Nguyen (Ha Giang province)	56	165
13	Thông Nguyên (Ha Giang province)	47	205
14	My Lam (Tuyen Quang province)	65.5	164
Truongson Block			
15	Bang (Quang Binh province)	100.0	214
16	Son Kim (Ha Tinh province)	78.0	189
17	Huyen Co (Quang Tri province)	70.2	189
18	Duong Hoa (Thua Thien – Hue province)	68.0	189
19	Kim Đa (Nghe An province)	73.5	162
Kontum Block			
20	Thach Tru (Quang Ngai province)	80.0	163
21	Hoi Van (Binh Dinh province)	85.0	147
22	Binh Chau (Ba Ria - Vung Tau province)	83.0	154
23	Tu Bong (Khanh Hoa province)	77.0	143
24	Nghia Thang (Quang Ngai province)	78.0	146
25	Thach Bich (Quang Ngai province)	65.0	145

4. GEOTHERMAL UTILIZATION

In Vietnam, the number of people working in the geothermal field is very small because geothermal brings very few jobs. Regarding the installation of geothermal power plants in Vietnam, the geothermal power plants is still in the future. Currently only one geothermal resource is in the exploration stages. The geothermal exploration progress is not fast because this is a new type of energy project in Vietnam, we lack seriously the engineers who have knowledge and experience in geothermal exploration so we have to hire foreign experts.

Almost all geothermal sources in Vietnam today are only used for direct utilization such as spa, bathing, hot water swimming pools, and recently people in Quynh Phu and Hung Ha districts of Thai Binh province have used hot water for warming the fish breeding ponds and chickens and pigs farm in the winter.

Currently there are only 2 Ground Source Heat Pump (GSHP) installation pilots in Hanoi but the only one pilot installed at the Vietnam Institute of Geosciences and Mineral Resources attached with 6 sensors installed for monitoring. The COP is calculated for cooling is 3.1 and for heating is 3.6 (Widiatmojo A. and Uchida Y. et al., (2019). The COP shows that the GSHP installation will bring energy efficiency for Hanoi area. One advantage for installing GSHP in northern Vietnam is that GSHP can be used for both summer cooling and heating in winter.

5. DISCUSSION

Geothermal applications for energy purposes have hardly been increased since 2015 until now. The reason is the geothermal application for power generation purposes still faces many difficulties, first of all, the investment in developing geothermal for power generation is high cost with high risks. The priority policies for developing this type of energy are not yet available, and the geothermal energy potential in Vietnam is still not attractive to investors. However, the development of geothermal resources for tourism purposes is strongly developed due to low investment costs and rapid return on investment. For tourism, investors often use hot water to make spa, bathing and swimming pools services. In recent years, local people in Hung Ha and Quynh Phu districts of Thai Binh province have also used hot water for warming the fish ponds and the pig's and chicken's farms in the winter.

For direct use, of course, it is beneficial to use natural hot water, but for energy generation, the price of electricity is much more expensive than electricity produced from fossil energy. However, so far no geothermal power plant has been built, so it is still unknown how much the cost of geothermal power generation and the electricity price that the government can buy for geothermal power producers. But it is certainly that the electricity price that the government will buy for geothermal power is high such as wind power with an average price of 8.8 cents/kWh or solar power with an average price of 9.0 cents/kWh.

Currently the Vietnamese government has had good policies to prioritize the development of renewable energy, but there are still no favorable policies for developing geothermal energy, although geothermal has been listed as a type of renewable energy in the legal documents. The reason is that there is currently no geothermal power plant and no investors have negotiated the electricity selling price with the government.

Parallel with the preferential policies, the government must pay attention to the training of human resources. In the immediate future, it is possible to put selected subjects into the teaching program for undergraduate students in geology and in techniques.

Try to integrate geothermal R & D programs into other socio-economic research programs if possible. Prioritize to allocate the favored capital and credit from the development fund, ODA fund and other bilateral lending funds for geothermal R & D as well as reinforce the human capacity.

In terms of capacity building, the Vietnamese government should reinforce the manpower by scientific and technological training for geothermal energy through cooperation projects.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

According to the "Assessment of Ability to Exploit Geothermal for Energy Production in Vietnam, 2013", the geothermal potential of Vietnam can be developed to 680 MWe. This number can be targeted until 2050. However, at the moment, it is possible to select the sources with the most geothermal potential and the favorable factors for developing geothermal power plants such as factors to access to the region, national electric grid connection. The development plan can be divided into 2 phases: Phase 1 - using geothermal resources those were intended to develop since 1995 (Table 3; Fig. 3) by ORMAT Inc. (ORMAT Inc., 1995) and phase 2 are the next potential sources (Table 4; Fig. 3). With this development plan the geothermal power generation capacity by 2025 could reach 155 MWe (Kasumi et al., 2018).

In order to temporarily plan for development, the author used the results of previous studies of geothermal potential and by calculating the method of Muffler, P. and Cataldi, R. (1978) to calculate the generating capacity of these most promising geothermal sources. Calculation results are shown in the table 3 and 4. Table 3 are geothermal sources selected by ORMAT since 1995 to generate electricity, but the project was unsuccessful due to various administrative and electricity costs. Table 4 are the new geothermal sources selected for further development, expected to 2025.

However, this is a plan basing on the available current situation of energy development in Vietnam. In fact, there is only one development project of geothermal power plant which is the development of Hoi Van geothermal prospect in Binh Dinh, South Central Vietnam (or Kontum Block). It is expected that the project will develop 10 -15 MWe and is going to the finalized period of exploration drilling. In addition, Vietnam has not yet specific plan for developing geothermal energy.

Table 3: Estimated power generation capacity for the geothermal potentials of "ORMAT's project in Vietnam"

Resource	Province	Sur. temp. (ºC)	Rer. Temp.(ºC)	Estimated Capacity (MWe)
Bang	Quang Binh	100.0	214	23.7
Thach Tru	Quang Ngai	79.0	163	13.3
Nghia Thang	Quang Ngai	78.0	146	10.7
Hoi Van	Binh Dinh	85.0	147	11.0

Danh Thanh	Khanh Hoa	69.0	127	7.2
Tu Bong	Khanh Hoa	78.0	143	9.7
Total capacity				75.6

Table 4: Estimated power generation capacity until 2025

Resource	Province	Sur. temp. (ºC)	Rer. Temp.(ºC)	Estimated Capacity (MWe)
Na Hai	Dien Bien	78.0	170	11.4
Son Kim	Ha Tinh	78.0	189	21.7
Duong Hoa	Thua Thien – Hue	68.0	189	18.5
Binh Chau	Ba Ria – Vung Tau	75.0	154	12.3
Quang Ngan	Ha Giang	62	170	15.3
Total capacity				79.2

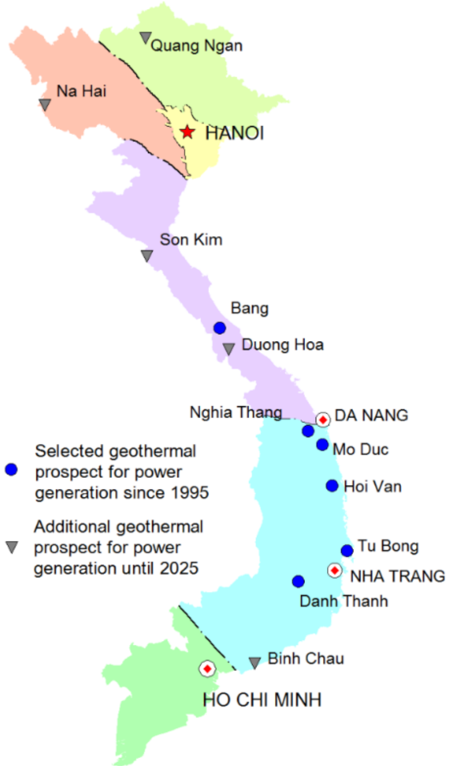

Figure 3: Target of power generation from geothermal resources until 2025

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APPENDIX

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0	0	34,560	174,635	18,060	66,780	0	0	5,880	18,550	60,000	265,000
Under construction in December 2019	0	0	600.0	3,060	220	814	0	0				
Funds committed, but not yet under construction in December 2019	15	130	7,400	37,740	1,040	3,848	0	0				
Estimated total projected use by 2020	0	0	35,160	177,695	18,280	67,594	0	0	5,880	18,550	60,000	265,000

TABLE 2. **UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019**

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)

2F = Double Flash H = Hybrid (explain)

3F = Triple Flash O = Other (please specify)

D = Dry Steam

3) Electrical installed capacity in 2019

4) Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity	Total Running Capacity	Annual Energy Produced 2019	Total under Constr. or Planned
						MWe[3)]	MWe[4)]	GWh/yr	MWe
Binh Dinh province, Vietnam	Hoi Van Geothermla Power Plant	N.A	N.A.		B	0	0		0
Total									

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality		Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
			Flow Rate (kg/s)	Temperature (°C)		Enthalpy[2)] (kJ/kg)		(MWt)	Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
				Inlet	Outlet	Inlet	Outlet				
Over Vietnam	Vietnam	B	168.6	52	27			17.63556	56.2	185.3195	0.3332177
Thai Binh province	Vietnam	F	9	41	27			0.527184	0.9	1.66194	0.0999653
Hanoi city	Vietnam	K	0.5	41	27			0.029288	0.041667	0.0769417	0.0833044
TOTAL										187.05838	0.5164875

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate - typically 3 to 4

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

6) Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Due to room limitation, locality can be by regions within the country.

Locality	Ground or Water Temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]		Heating Equivalent Full Load Hr/Year[4]	Cooling Equivalent Full Load Hr/Year[4]	Thermal Energy Used[5] (TJ/yr)	Cooling Energy[6] (TJ/yr)
					Cooling	Heating				
Hanoi, Vietnam	27	5 kW	1	V	3.1	3.6	528	1232	346.8	1117.3
TOTAL		5 kW	1	V	3.1	3.6	528	1232	346.8	1117.3

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184

or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming	0.527184	1.66194	0.09996532
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	17.63556	185.3195	0.333217734
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	5 kW	1464.1	
TOTAL	18 MWt	185.3 TJ/yr	0.433183

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	7				2.4
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total		7				2.4

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	15	25	4	3	4	4
2016	15	25	4	3	4	4
2017	8	25	3	3	2	3
2018	8	25	2	3	2	3
2019	4	25	2	3	1	3
Total	50	125	15	15	13	17

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0					
2000-2004	0					
2005-2009	0.1					
2010-2014	0.5					
2015-2019	2.1	2			95	5